Design and Development of Body Panel for UTP's Shell Eco-Marathon Vehicle

by

ARUJENDRAN A/L M.K. GANESAN

Dissertation submitted in partial fulfillment of
the requirements for the
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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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(Mr. Muhamad Ridzuan bin Abdul Latif)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ARUJENDRAN A/L M.K. GANESAN

ABSTRACT

Shell Eco Marathon Asia is a fuel efficiency competition in which one liter of petrol is given and the car that travels the furthest is the winner. The goal of this project is to design and develop the body panel for the UTP's Shell Eco Marathon vehicle which is lightweight and rigid. Literature review of past designs and material used has been reviewed and researched to get an idea of suitable lightweight materials and design to be used and further enhanced. To design the body panel, CATIA V5 R16 was used to simulate the design of the new body panel. Dimensions for the simulation were taken using the chassis which has been agreed by the team to be reused. Mould was then developed by using plywood and zinc sheets to deform to the desired shape of the body parts. After mould was developed, we moved on to the fibre glass layout process in which the method used was resin infusion. After infusion done, each part were left to dry under the hot sun for about 6 hrs and then dry body parts were removed from the mould. Body parts were then fitted to the chassis with modifications done by cutting excessive fiber glass and finishing was done by using stickers to make it look better. The result of this project showed a significant 52% in weight reduction compared to the previous body panel. It also demonstrated higher rigidity, less thicker panel and higher hardness compared to the previous body panel. In conclusion, the objective of the project which is to design body panel which is lightweight, strong and affordable for UTP's Shell Eco-Marathon vehicle and manufacture and assemble parts of the body panel to have a complete car has been successfully achieved.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my utmost gratitude to my supervisor, Mr. Ridzuan bin Abdul Latif, for his undivided attention and guidance throughout my Final Year Project. He had contributed by taking time off and providing me with constructive ideas and recommendations which were crucial towards the completion of this project.

On another note, I would also like to thank my Shell Eco Marathon teammates who helped me by sharing their ideas and skills and also taught me the value of teamwork.

Thank You,

ARUJENDRAN A/L M.K. GANESAN

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INTRODUCTION.

1.1 Project Background

Optimization of petrol consumption of a vehicle is widely discussed topic in the world today. A fuel efficient car not only saves cost but saves the environment from excessive fossil fuel emissions from vehicles. Researchers have been extensively seeking solutions in order to achieve the goal above.

Shell Eco-Marathon is a challenge where cars are built to achieve the goal of producing fuel efficient cars. The fuel efficiency is measured as the Shell Eco-Marathon cars are only allowed 1 litre of petrol during the race in which the car that travels the furthest distance wins the race. This race will help enhance the knowledge and help generate ideas to the automotive industry on building future cars with higher fuel efficiency and lesser environmental impact.

This project is to design and develop a Shell Eco Marathon car's body panel which is to be lightweight and rigid. Lightweight material is to be used as the body panel of the car in order to have a significant weight difference between the previous car and also the new car which is to be designed.

1.2 Problem Statement

The previous vehicle which is the Shell Eco Marathon 2010 vehicle was heavy and had a weak body panel structure. The excessive weight of the body panel directly causes the increase in fuel consumption of the vehicle. Secondly, the weak structure of the body panel causes the body to fold or bend easily.

1.3 Objective

- To design body panel which is lightweight, strong and affordable for UTP's Shell Eco-Marathon Vehicle.
- Manufacture and assemble parts of the body panel to have a complete car.

1.4 Scope of Study

Scope of study of this project is to research and design a one man vehicle which is lightweight and strong for the Shell Eco-Marathon race. CATIA V5 R16 software is to be used to model the design of the vehicle using dimensions from the chassis of the previous vehicle.

Mould is developed and resin infusion process is done as part of the manufacturing process to fabricate the body panel parts. After infusion and removal of body panel from the mould, assembly and fitting into the chassis is to be done.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review of Past Designs of Body Panels.

2.1.1 Pac-Car II

The Pac-Car II is the current world record holder which can travel a distance of 5385 kilometers with hydrogen equivalent to 1 liter of gasoline (ETH Pac Car II, 2009). This world record is certified by the Guinness Book of World Records. The project was done by a group of students and an experienced team leader from ETH Zürich (Swiss Federal Institute of Technology).

The vehicle has a self supporting body design which does not require a chassis to support its body structure. The vehicle uses a monocoque carbon fiber body structure which does not need an internal frame or truss in order to support the external forces or vehicle weight. Furthermore, this chassis would help reduce the weight of the vehicle without disturbing its rigidity. The monocoque design compromises the body panel as the whole structure is one piece.

The drawbacks of using a monocoque design are as below:

1) High restriction on vehicle accessibility and also modification to vehicle as the body is of one piece and is body is highly integrated.
2) Expensive and difficult manufacturing process.
3) Narrow opening for driver to access vehicle in and out of driver's cockpit.

Figure 2.1: Pac-Man II (ETH Pac-Car II, 2009)

2.2 Other Designs.

Recent entries to the Shell Eco-Marathon race have seen cars with different designs. Every vehicle has its own unique design in order to optimize the weight of the car and aerodynamics of the vehicle. Most importantly, it can be seen that all vehicles have a narrow streamlined frontal design. This can be seen as to reduce the amount of material used as well as decreasing the weight of the car.

Vehicles entering the competition have varied designs of either a monocoque design as has been mentioned above or a vehicle with internal frames or truss which would require a body panel. The most common internal frames used are ladder chassis, space chassis, and backbone chassis. The current UTP vehicle uses the ladder chassis. The chassis is considered to be one of the oldest chassis and is also still used in the automotive industry till today.

Using the chassis, the design of the current UTP vehicle is a design inspired by the Shinkasen 500 train and a teardrop. The shape was chosen to reduce drag forces as well as to reduce amount of material to be used as the body shape is narrow.

Figure 2.2: Shinkansen 500 (Shinkansen 500, 2010)

2.3 Body Panel Materials.

Pac-Car II has a monocoque body design using carbon fibre material. It is the current world record holder. Carbon fibre is a quite a common material used as the vehicle body panel as it is also used by the Remmi 7 team from Tampere University of Technology (Tampere University of Technology, 2009). The Remmi 7 team furthest distance travelled with per litre of gasoline with a distance of 3306 km. The body design of the Remmi 7 is almost similar to that of Pac-Car II but Remmi 7 has a internal frame or truss which is a space frame chassis.

Figure 2.3: Remmi 7 (Tampere University of Technology, 2009)

On the other hand team PINGU II which was created by HAW Hamburg came out with a very unique design with frontal shaped like a head of penguin(HAW Hamburg Pingu II, 2009). The body uses a plexiglass body panel material and the car is understood to have travelled a distance of 1622 km per litre of gasoline.

Figure 2.4: Pingu II (HAW Hamburg Pingu II, 2009)

The current UTP vehicle Shell Eco-Marathon vehicle uses a body panel material of fibre glass. Fibre glass is said to have fulfilled the criteria of being lightweight, rigid and low cost. The current issue faced by the current UTP vehicle is the body panel was not well manufactured and molded therefore the body is not as rigid as it should be. The chassis of the current vehicle is ladder chassis.

Figure 2.5: UTP Shell Eco-Marathon Race Vehicle

CHAPTER 3
METHODOLOGY

3.1 Project Planning.

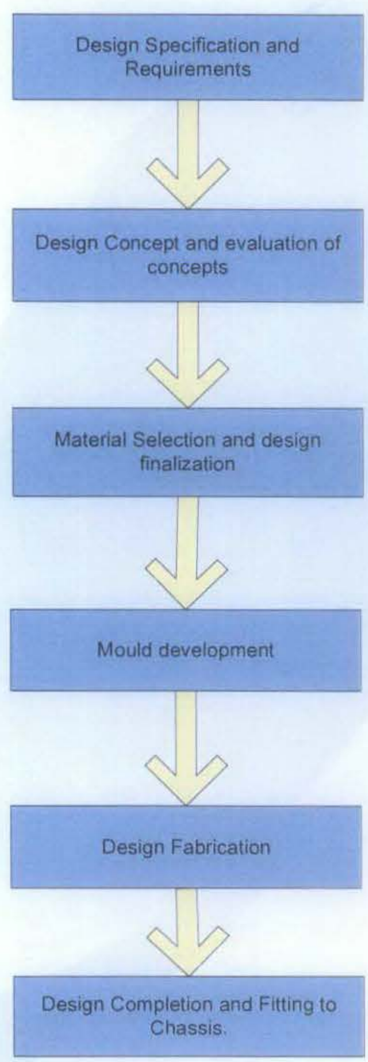

Figure 3.1: Project Planning

Project planning explains the phases of task to be completed in order to make the project successful. Each task has to be completed as shown sequence in figure 3.1.

3.2 Design Specification and Requirements.

The Shell Eco-Marathon has guidelines which are to be followed by every team concerning the design physical constraints of each vehicle's are as below:

1) Maximum height must be less than 100*cm*.
2) The maximum height measured the top of the driver's compartment must be less than 1.25 times the maximum track width between the two outermost wheels.
3) The track width must be at least 50cm, measure between the midpoints where the tyres touch the ground.
4) The wheelbase must be at least 100cm.
5) The maximum total vehicle mist be less than 130cm.
6) The total length must not exceed 350cm.
7) The maximum vehicle weight excluding the driver is 140kg.

(Shell Eco-marathon Official Rules 2011, Section 3A Article 26)

The rules and regulations by Shell Eco-Marathon will not be a problem to the team as the current chassis is said to be maintained therefore the design of the vehicle will not vary much.

3.3 Design Concepts.

The body design of the vehicle is to be of the same concept as the previous body panel which has a teardrop shape. This is due to the use of the existing chassis which has been agreed and approved by the team principal.

3.3.1 Design Concept A.

Design concept A is the same design as the previous Shell Eco Marathon vehicle as show n in figure 3.2 below. It is a one piece/part body panel design. The material to be used for this design concept is fiber glass which meets the criteria of being a lightweight and rigid body panel. Concept Design A has its fair share of pros and cons. The pros of this model is it can be manufactured with the help of the current in-house expertise as they already have the experience of manufacturing the vehicle body panel before. The con of this concept is the vehicle would be difficult to access in any emergency cases. For instance if the engine has a problem, the engine would be difficult to access as the body part is of one piece and the whole body has to be removed from the chassis to access the engine. Secondly, if there is a modification to be made to the body panel it would be difficult.

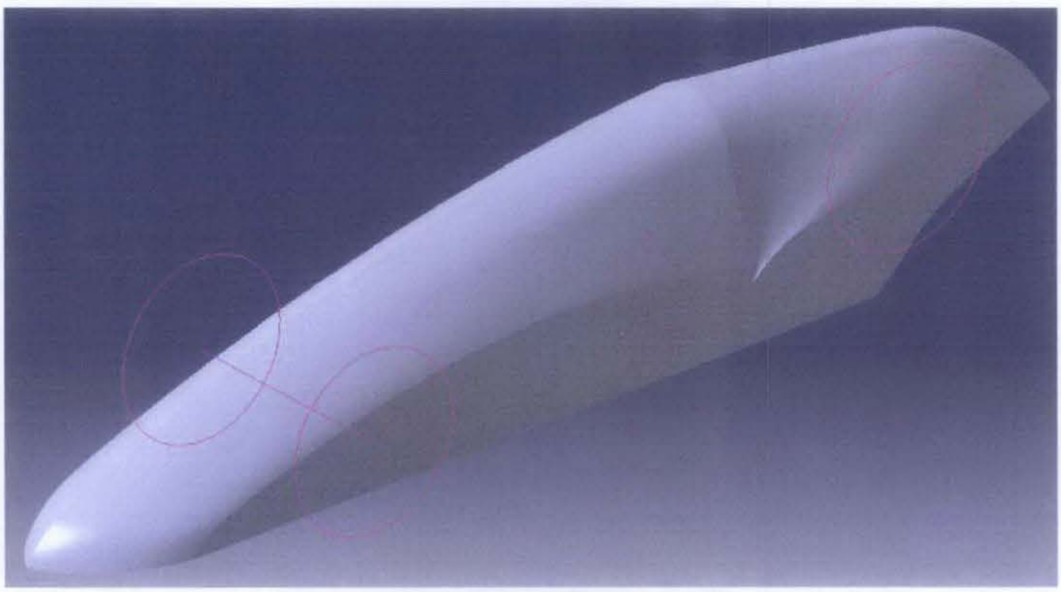

Figure 3.2: Previous Body Panel Design

3.32 Design Concept B.

Design Concept A is similar to Design Concept B except that this design is to have a 3 part body panel in which the engine compartment of the vehicle will have a separate body panel from the driver's compartment. The vehicles fiber glass material is to be maintained as well as it lightweight and rigid. The difference between the current design and this concept is that, Concept Design B would have a three part body panel design in which it would be divided to front part, engine compartment body panel and driver's compartment body panel and it has an open middle body part which will be replaced with a transparent deformable plastic. This design would solve the problem of Design Concept A, as with this design the vehicle would be easily accessible in times of break down or modifications. The body material is to be maintained which is Glass Fiber as it is lightweight, rigid and strong.

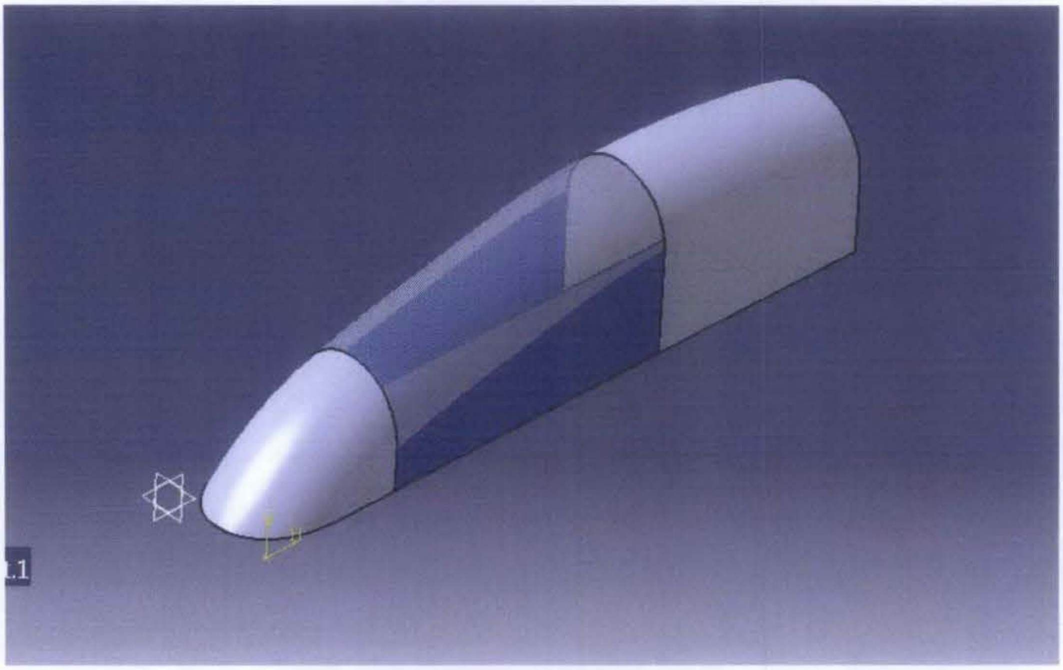

Figure 3.3: New Body Panel Design

The design concept of the new body panel was drafted using the CATIA V5 R16 software in order to have an idea of the mass and also the design of the new body panel compared to the old body panel. These will serve as the base plan for the project to be further analyzed and improved. The transparent part of the vehicle will be the door of the vehicle which will be covered using a deformable transparent plastic.

3.3.2.1 Design concept B weight.

The density of resin and fiber glass is based on sample calculation as below:

Typical Glass fiber = 2.6 g/cm³ or A

Typical resin = 1.3 g/cm³ or B

Therefore Assume that the glass content by weight is 50 %

Therefore in 100 grams of sample composite, 50 grams is fiber and 50 grams is resin.

Determine the Volume:

volume of resin = Total grams of resin / density of resin

50 grams /1.3 g/cm^3 = 38.46 cm^3 resin

Volume of fiber glass = Total grams of fiber glass / density of fiber glass

50 grams / 2.6 g/cm^3 = 19.23 cm^3 fiber

Total volume = volume of resin + volume of fiber glass

Total = 38.46 + 19.23 = 57.69 cm^3

Determine volume percents:

Volume percentage of resin = (volume of resin/total volume) × 100%

Volume percentage of resin = 38.46 / 57.69 x 100% = 66.7 % of resin or C

Volume percentage of fiber glass = (volume of fiber glass/total volume) × 100%

Volume percentage of fiber glass = 19.23 / 57.69 x 100% = 33.3 % of fiber glass or D

Now you can figure out the density from the volume percents

divide the percents by 100 and multiply by the density,

$C/100 \times A$

$= .667 \times 2.6\ kg/m^3 = 1.733\ kg/m^3$ fibre glass or E

$D/100 \times B$

$= .333 \times 1.3 = 0.4329\ kg/m^3$ resin or F

Add these together; this is the composite density of fiber glass and resin.

E + F = Total composite density of resin and fiber glass.

$1.733 + 0.4329 = 2.166\ g/cm^3 = 2166\ kg/m^3$

3.4 Material Studies and Selection for body panel.

The material selection of the vehicles body panel depends on two main criteria which are:

a) Weight and strength of the material.
b) Cost of the material.

The material selected must be able to withstand drag forces when the vehicle is driven at about 35km/h maximum without any noticeable deflections. The material should also be lightweight in order for the vehicle to be lightweight. The resin to be used is a vinyl ester resin with MEKP and cobalt as hardeners.

3.4.1 Feasible Materials

There are 3 feasible materials which the body panel can be chosen from are:

a) Aluminium

Aluminium is material of low density and high strength. It fits the lightweight criteria and it is also corrosion resistance and recyclable. Fabricating aluminium is rather difficult as it is easily deformed due to its low elasticity.

b) GFRP

Commonly known as fibreglass, GFRP is widely used in the automotive industry. GFRP is advantageous due to its high formability, controllability of material properties, wide scope of applications, and relative ease of production. GFRP has a lower density compared to aluminium but its production must be carefully controlled to achieve the desired properties and effect. It easily formable but not easily repaired and cannot be recycled. GFRP also provides good corrosion resistance as well as good dimensional stability and scratch resistance qualities (Davies 2003).

c) CFRP

Commonly known as carbon fibre, CFRP is very similar in its advantages and disadvantages to GFRP however is has a lower density and higher strength. These improved material properties lead to a much higher material cost. CFRP is 30% lighter than GFRP, making it a better material albeit it's higher cost (Balfour 2000).

For this project, Aluminium is deemed as not a suitable material to be used as it is easily deformed due to its low elasticity. The shape of the body is an important factor for the vehicle design as it the car is to have a smooth surface and heavily contoured. This factor has ruled out aluminium in the selection process.

In between CFRP and GFRP both materials are suitable has it is both lightweight as well has high strength. The materials are also easily formed and would be easy to fabricate to ensure a smooth and well contoured design. It is produced by liquid matrix and reinforced fiber which would be easy to form. The manufacturing process would be simple as a mould would be used to hold the liquid matrix and once hardened it would give the desired shape as the mould.

GFRP would be chosen over CFRP even though CFRP has 30% lower weight compared to GFRP due to cost issues. CFRP is known to be expensive and it does not adhere to the second criteria of material selection. Therefore due to cost restrictions, GFRP is the more suitable material to be chosen.

3.5 Mould Development

Mould development is crucial in obtaining the desired body panel parts. Therefore proper dimensions are to be taken in order to be able to fit the body panel to the chassis perfectly. Mould was developed using plywood and deformable zinc sheets.

3.6 Design Fabrication

Fabrication or manufacturing method is by using the resin infusion method and resin to be used as said above is the vinyl ester resin with MEKP and cobalt as the hardeners and cure time of resin of 30 minutes.

3.6.1 Previous Fabrication Method.

The previous manufacturing process is also known as the wet lay-up process using a mould. The shape of the mould will determine the shape of the body panel part. The mould is first applied with mould releasing agent to prevent the fiberglass part from adhering to the mould. Resin and fiberglass are deposited on the mould and rollers are used to compress the wet composite which evenly distributes and removes air pockets.

The process is repeated by laying another layer of fiberglass and resin onto the previous layer and compressed using the roller. After a few hours the resin would've cured and hardened, the part is removed from the mould and excess material is trimmed and the body part is ready to be assembled. The resin used is polyester resin matrix and with 2 layers of fiber glass.

3.6.2 Resin Infusion Method.

For the new body panel resin infusion method is to be used to attain a lighter and rigid body panel. Resin infusion method is much more complicating than the straight forward wet lay out process but it has a better end result to the product. The resin infusion method requires more time and equipments such as suction pump, resin trap, compoflex, spiral tubing, vacuum bag and tachy tape. The function of each of the equipments is stated as below:

i. Suction Pump – the pump is used for suction purpose of resin from the start point to the end point in which the suction pump is connected to a resin trap.
ii. Resin Trap - Trap excessive resin from entering the pump which will damage the equipment.
iii. Compoflex - Used as a distribution net for the resin infusion to take place.
iv. Sealant/tacky tape – Seal off the vacuum bag and it is important that the sealant tape has no air pockets to have a proper infusion process.
v. Vacuum bag – The final layer on the body panel which is elastic and provides vacuum conditions.

The steps of manufacturing the body parts are as below:

i. The mould for front body panel, middle body panel and rear body panel will have to be constructed first.
ii. Plywood and deformable zinc sheets were used to create the mould for the front and rear body panel. As for the middle part the mould used was a sheet of aluminum rectangular shaped mould.
iii. After the completion of making the moulds, the fiber glass but cutting it into its desired shape and placed on the mould.
iv. Foams were used in between the fiber glass lay out in order to stiffened the body panel as show in Figure 3.4

Figure 3.4: Cutting of foam into strips.

v. Wax will be wiped on the mould as it would behave as a mould releasing agent. This is to have an ease in separating the body panel from the mould once the infusion is complete.

vi. Tacky tape or sealant tape is used to cover the outside perimeter of the mould.

vii. 3 layers of fiber glass is placed on the mould followed by strips of foam and then another 3 layers of fiber glass is placed on the strips of foam.

viii. Compoflex is cut into proper dimension and placed on the 6 layers of fiber glass.

ix. Netting and then the vacuum plastic bag is placed on the lay outs and pressed against the tacky tape to prevent air pockets.

x. The suction pump is switched on, the vacuum bag will compress the lay out and the infusion would be ready to take place. The images below show the resin infusion process.

xi. The transparent deformable plastic which behaves as a door at the middle part of the body is made by cutting sheets of metal and making it as a mould with a shape of a hemisphere and nailing the thin deformable plastic onto it.

xii. Brackets are made and attached on the deformable plastic to grip on the chassis.

xiii. The layup of the resin infusion set-up is shown in Figure 3.5.

3.7 Design Completion and Fitting into Chassis.

Design will be inspected before fitting into the chassis as minor changes such as cutting of excessive fiber glass can still be made.

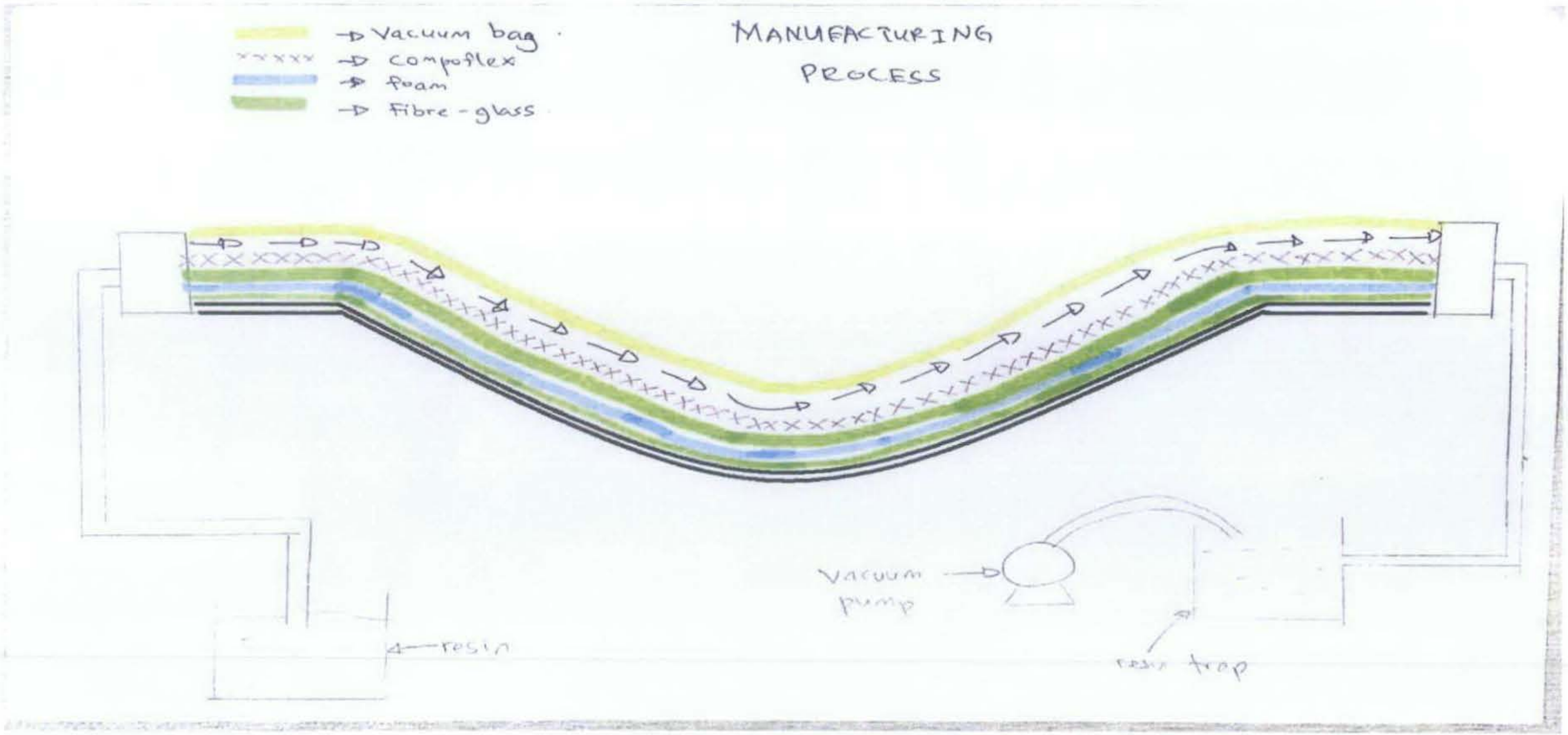

Figure 3.5: Manufacturing Process

CHAPTER 4
RESULTS

4.1 Body

4.1.1 Design Basis.

Design concept B has been chosen for this project which is slightly different from design concept A or the previous design of the vehicle. Based on the density calculation following the calculation steps from chapter, the density is an estimated 2166 kg/m^3. Using CATIA V5 R16 the weight estimation is about 23 kgs which is about 21% lighter compared to the previous body panel or design concept A. The difference between design concept B and design concept A is the door of the vehicle. Previously the door of the vehicle is just a small opening at the middle part of the body made of fiber glass. On the other hand, design concept B has been designed in a way that a transparent deformable plastic is used as the door which would be fitted to the chassis. This design makes the car much lighter and accessible as well as enhances the view of the driver.

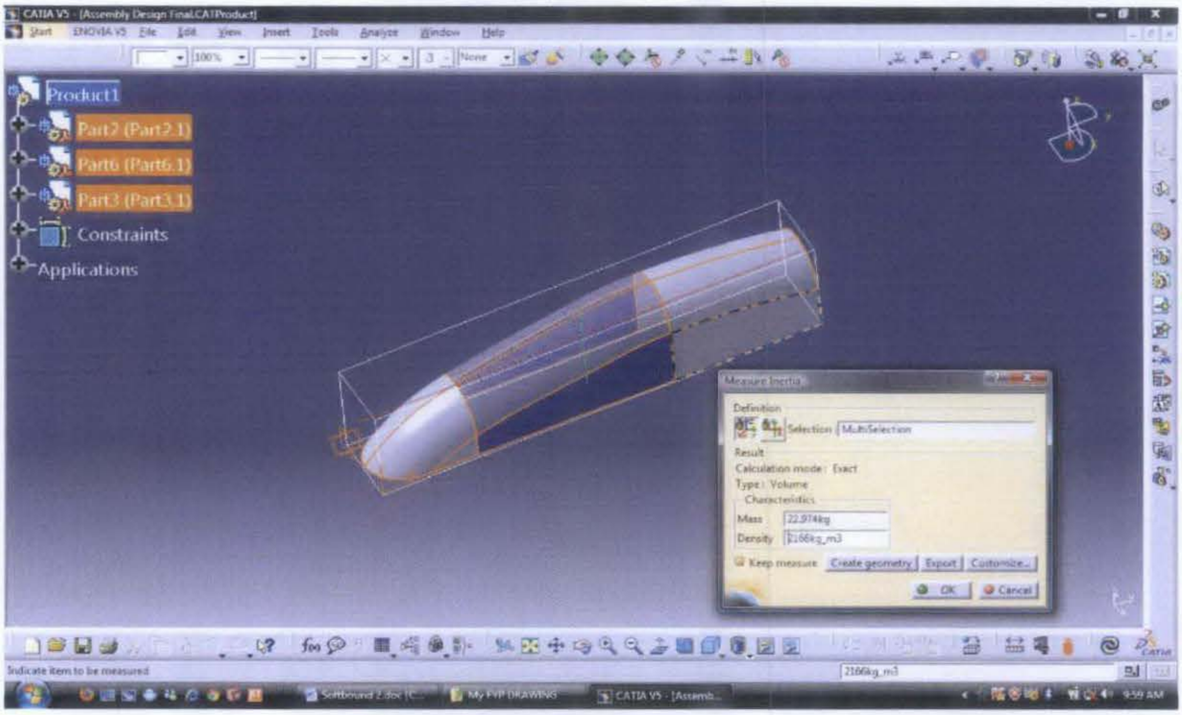

Figure 4.1: Estimated Weight

4.1.2 Design Manufacturing.

Design was manufactured using the resin infusion method. The resin infusion of the 3 body parts are shown as the figures below:

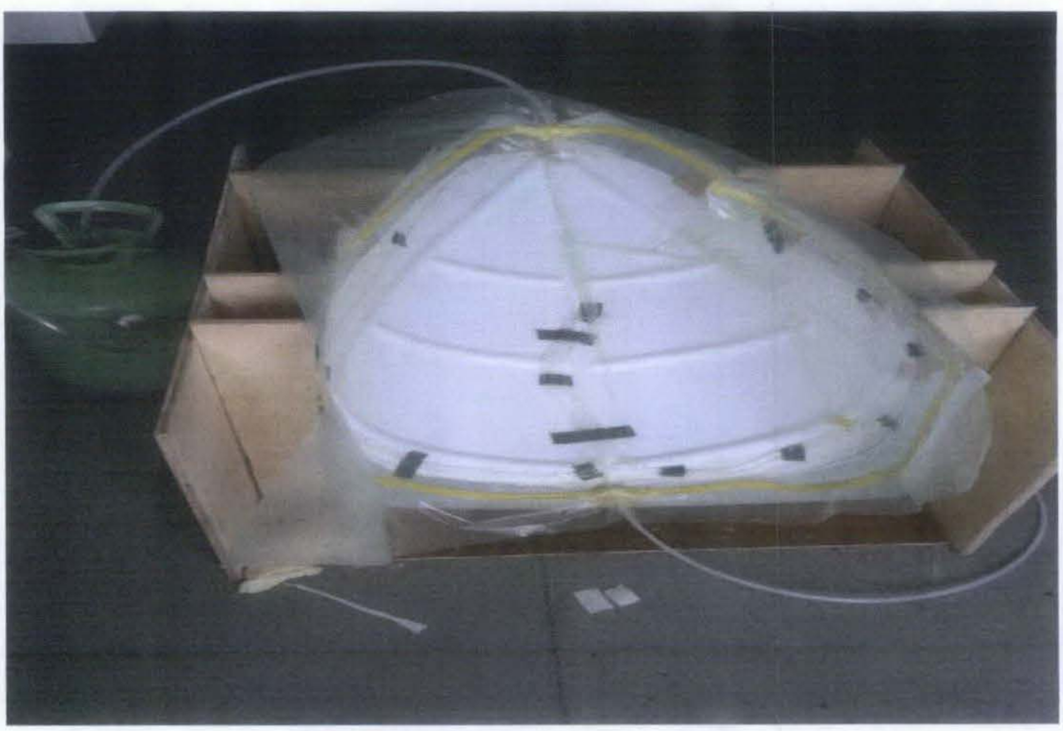

Figure 4.2: Front Body Panel

As it could be seen in Figure 4.4, the front body panel has been compressed due to the suction of the motor pump attached to it. The ribs of the body panel are clearly visible and end product is visible. The compression forces the excessive resin to the resin trap which will help give a thin but rigid body panel. The front body panel had a weight of 2kgs.

Figure 4.3: Middle/Side Body Panel

The side body panel is made on a flat mould and as the figure above shows it is properly compressed and infusion would take place perfectly. The ribs of the body panel which is made of the foam explained in chapter 3 is clearly visible. Excessive resin will be flowed thru the tube into the resin trap which will reduce the amount of weight caused by the resin and reduce the thickness of the body panel. Since it is a side body panel, two body panels are made for the middle part, for the left side and right side. The weight of each side body panel was approximately 1.5kgs.

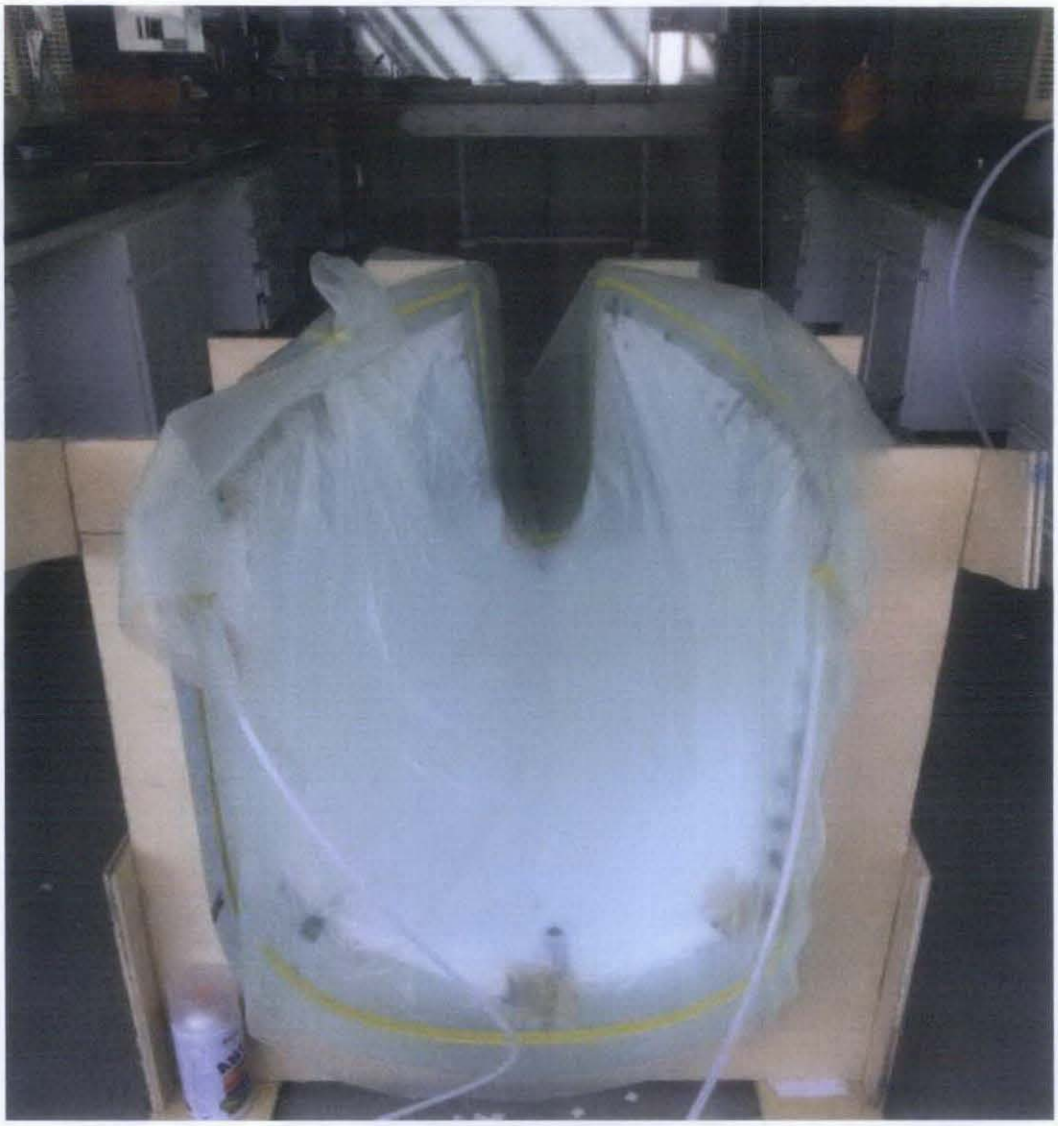

Figure 4.4: Rear Body Panel

The rear body panel is bigger compared to the front body panel and then side body panel. As it could be seen in the figure above the vacuum bag is not properly intact or compressed compared to the front and side body panel. This are due to three reasons as stated below:

i. Suction pump is not powerful enough.
ii. Two zinc pieces are used to make the mould which means there is an overlap of one zinc piece on another which causes air to easily escape even though the overlapping zinc area has been sealed.
iii. Tacky tape/ Sealant tape used is of low grade. Therefore the vacuum bag could not be properly sealed off. Therefore there were air pockets around the sealant tape area.

In order to overcome the problem faced above, a vacuum pump was used to replace the suction motor which we had. The compression was much better using vacuum pump and the resin infusion took place. The weight of the rear body panel was approximately 7kgs.

4.1.3 Improvement of Design

TABLE 1: Comparison of new and previous body panel.

SPECIFICATIONS/ MODEL	NEW BODY PANEL (resin infusion method)	OLD BODY PANEL (wet lay out method)
MASS (TOTAL)	12KGS	25KGS
COMPARTMENT (S)	3	1
HARDNESS (VICKERS)	418 HV	304.7 HV
THICKNESS	2mm	5-10mm

Based on the table above it can be derived that the weight reduction is about 52% which is very satisfying as the objective of my final year project has been achieved. The new body panel is less thicker compared to the old body panel but it shows higher strength and rigidity. The figure below clearly shows the difference in rigidity of the new body panel and the old body panel. The thickness of the previous body panel varies from the front to the rear body panel. The resin is mostly deposited at the front body panel which gives it a very thick front part and thin surface at the back which has a very low rigidity. The table justifies the use of resin infusion method as the outcome is much more desirable compared to that of wet lay out method.

Figure 4.5: Previous Body Panel (flipped)

Figure 4.5 shows the previous body panel being flipped upside down. The rigidity of the previous body panel is obvious from the figure above. It can be seen that the rear part has no rigidity that it spreads wide open. Figure 4.6 which is the new rear body part can be seen as rigid and has a higher strength compared to the previous body panel. It has no sign of slight deflection and the outcome is satisfactory.

Figure 4.6: New Body Panel (Flipped)

Figure 4.7: Top view of rear part of previous body panel.

Figure 4.8: Top view of middle part of previous body panel.

Figure 4.7 and 4.8 shows the top view of the previous body panel at the rear part and middle part. As it could be observed that the body panel is not strong and has a very low rigidity. The body panel can be folded even though the amount of fiber glass layers used is almost the same as the new body panel. This shows the difference of using the resin infusion method compared to the wet lay out method. Resin infusion clearly gives a better result compared to the simple wet lay out process as the excessive resin is difficult to be removed and also the compression by rollers isn't sufficient to create a rigid surface.

Figure 4.9 shows the completed body panel design after the cutting to be fitted into the chassis. The body panel can be observed as much more rigid and is able to stand without and noticeable deflections on the body panel. Even though the body panel is much more thinner compared to previous body panel, the resin has been properly spread and compressed thru every part of the fiber glass which helps it to have more strength and less resin void area like the previous body panel.

Figure 4.9: Completion of Design

Figure 4.10: Transparent deformable plastic as door.

The transparent deformable plastic is used as the door of the vehicle. The transparent plastic gives the driver a bigger view of the surrounding during the race compared to the previous vehicle which has a limited view. As it can be observed it is supported by thin zinc metal structure which has a shape of a hemisphere and brackets at the bottom to grip onto the chassis.

Figure 4.11: Body Panel fitted to chassis

Figure 4.11 shows the body panel fitted to the chassis and the complete vehicle for the Shell Eco Marathon 2011 race. The body was fitted to the chassis using bolts and nuts. The 3 part body panel is preferred by the team as the engine and other body parts can be accessed easily if there is a problem as only the required body panel has to be removed.

CHAPTER 5

CONCLUSION and RECOMMENDATION

5.1 Conclusion

In conclusion, the objective of this project which is to design body panel which is lightweight, strong and affordable for UTP's Shell Eco-Marathon Vehicle and manufacture and assemble parts of the body panel to have a complete car has been successfully achieved. New body panel recorded a massive 52% of weight reduction compared to the previous body panel and also is much more rigid has shown in chapter 4.

5.2 Recommendation

For future project works, I would recommend that proper or a better equipment is purchased in order to design a much lighter body panel. Equipments such as a higher capacity suction pump, higher grade sealant tape, and a new vacuum bag which is specifically for resin infusion to be purchased.

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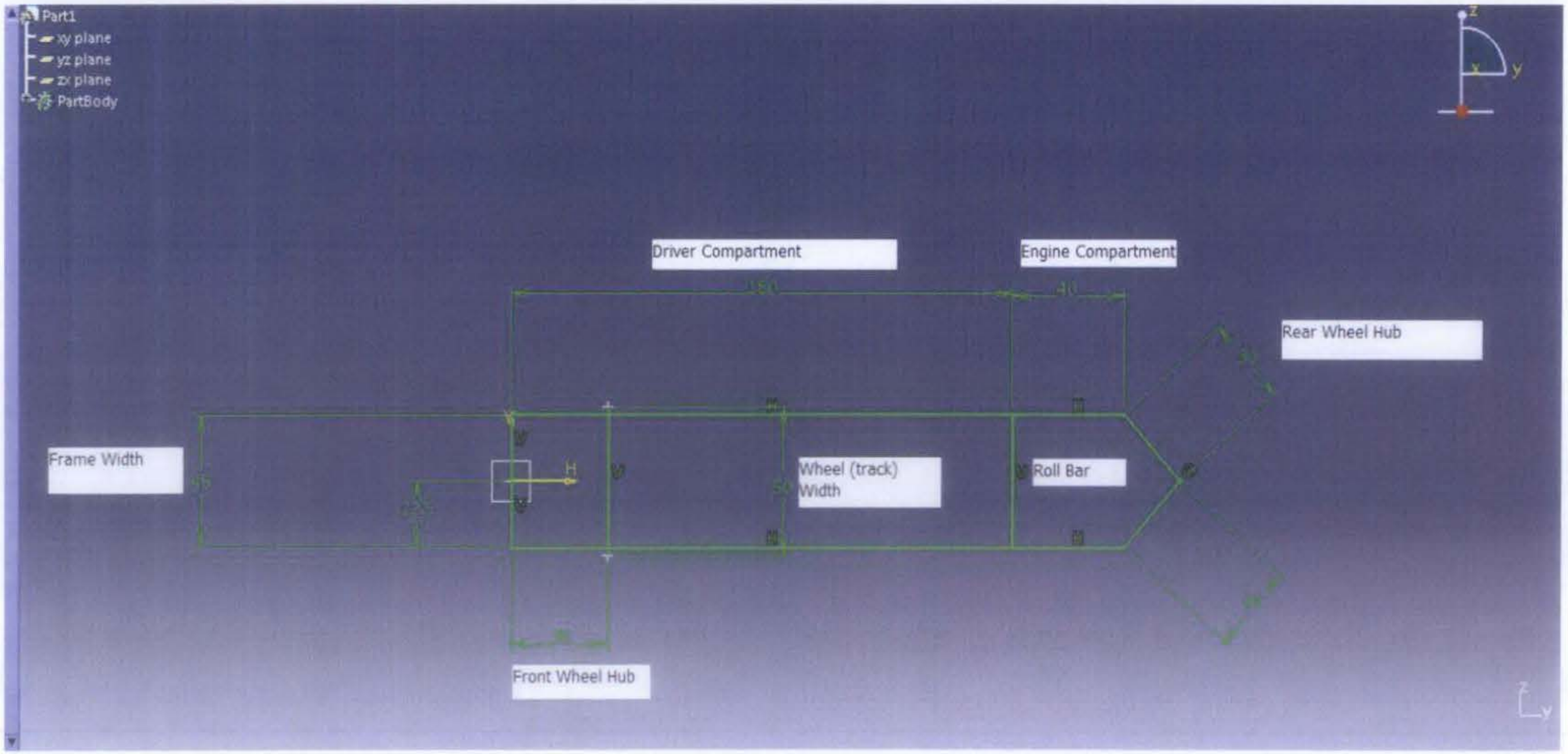
APPENDICES.

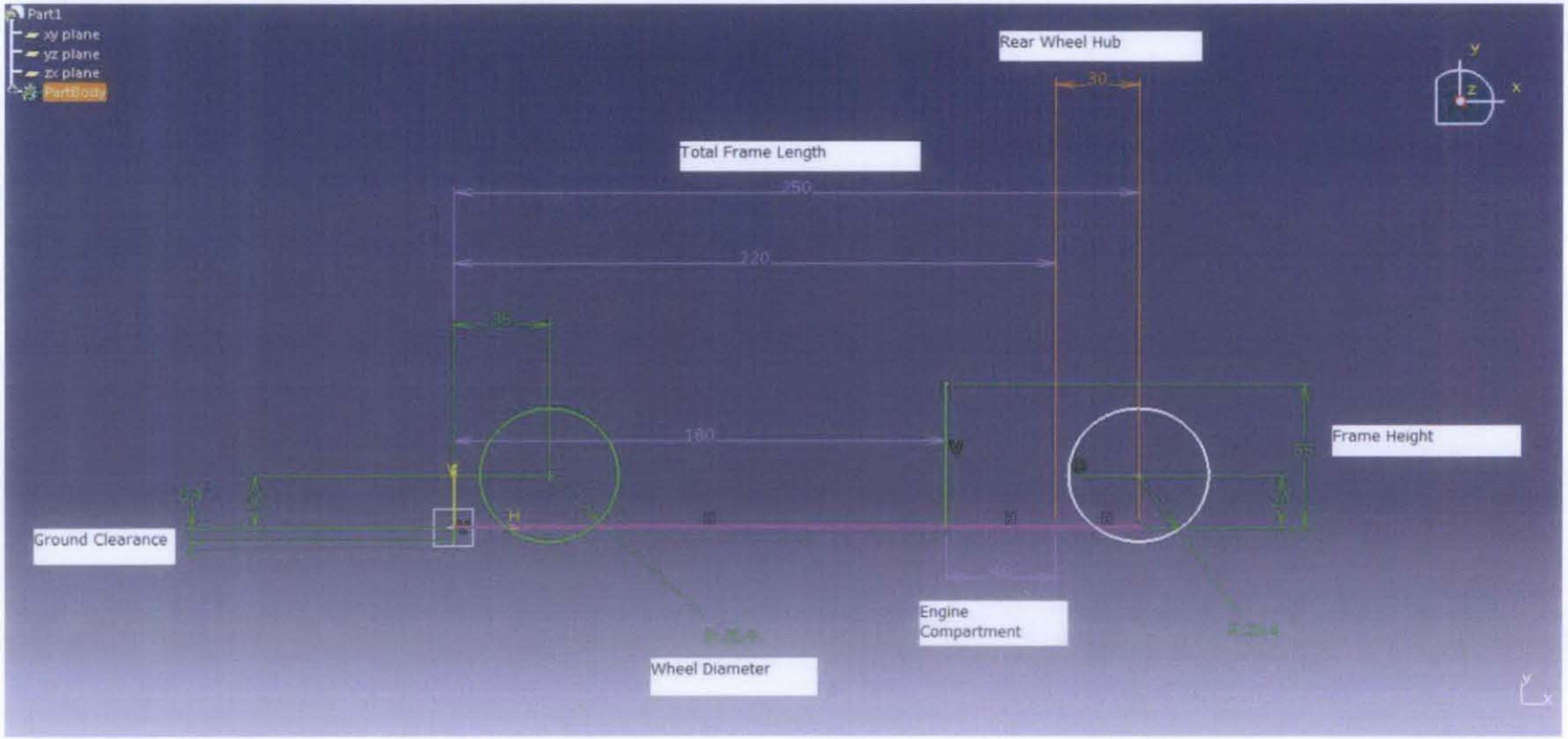
Gantt Chart.

Tasks/Month	**July**	**July**	**August**	**August**	**September**	**September**	**October**	**October**
Information Gathering								
Literature Review & Dimension Analysis								
Material Selection & Design Selection								
Manufacturing Method								
Analysis of Design								

Top view of chassis of vehicle.



Side view of chassis of vehicle.


Part1
xy plane
yz plane
zx plane
PartBody
Rear Wheel Hub
30
Total Frame Length
250
220
35
180
Frame Height
55
Ground Clearance
Engine
Compartment
Wheel Diameter